

# Meteorology of Lake Tahoe Basin

December 14, 2005  
California Air Resources Board

Jim Pederson

# Overview of Topics

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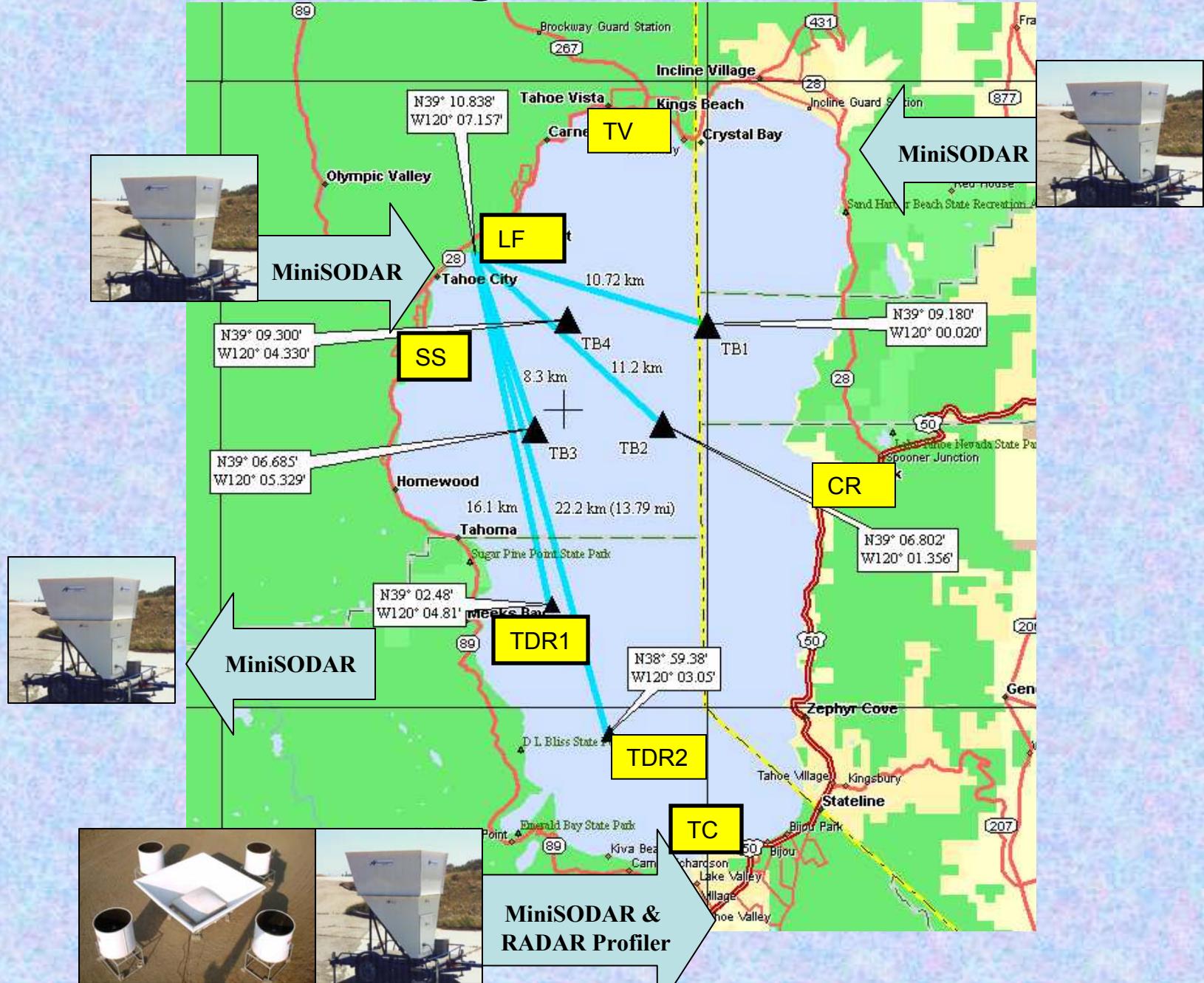
- Measurements in 2003
- Regional Flows
- Local Effects
- Temporal Consistency
- Spatial Complexity of Winds
- Non-Equilibrium Conditions
- Spatially Complex Mixing

# 2003 Meteorological Observations

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- Surface Winds, Humidity, Air & Water Temp
  - Piers & buoys (UCD), AQ sites, NWS
- Boundary Layer - MiniSODAR
  - Range ~15 - 200 m; 5 m resolution
  - SLT Airport, Tahoe City, Incline, Big Hill
- Upper BL & aloft – RWP/RASS
  - winds, temperature, 80 m resolution
  - Radar Wind Profiler (RWP) range ~ 120 – 3,000 m
  - RASS range ~ 120 – 1,000 m
  - SLT Airport, Grass Valley

# Meteorological Measurements



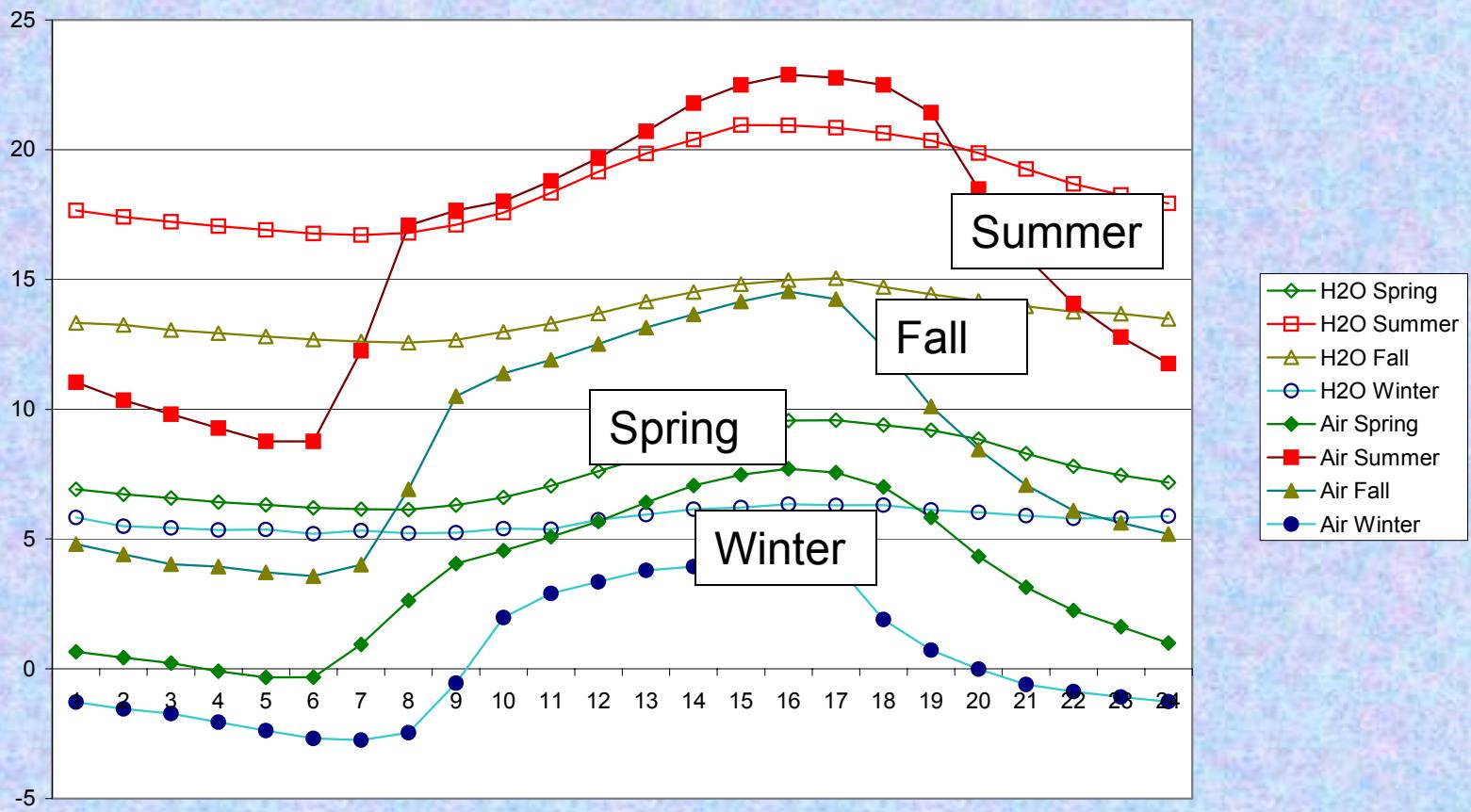
# Meteorological Aspects of Tahoe Basin

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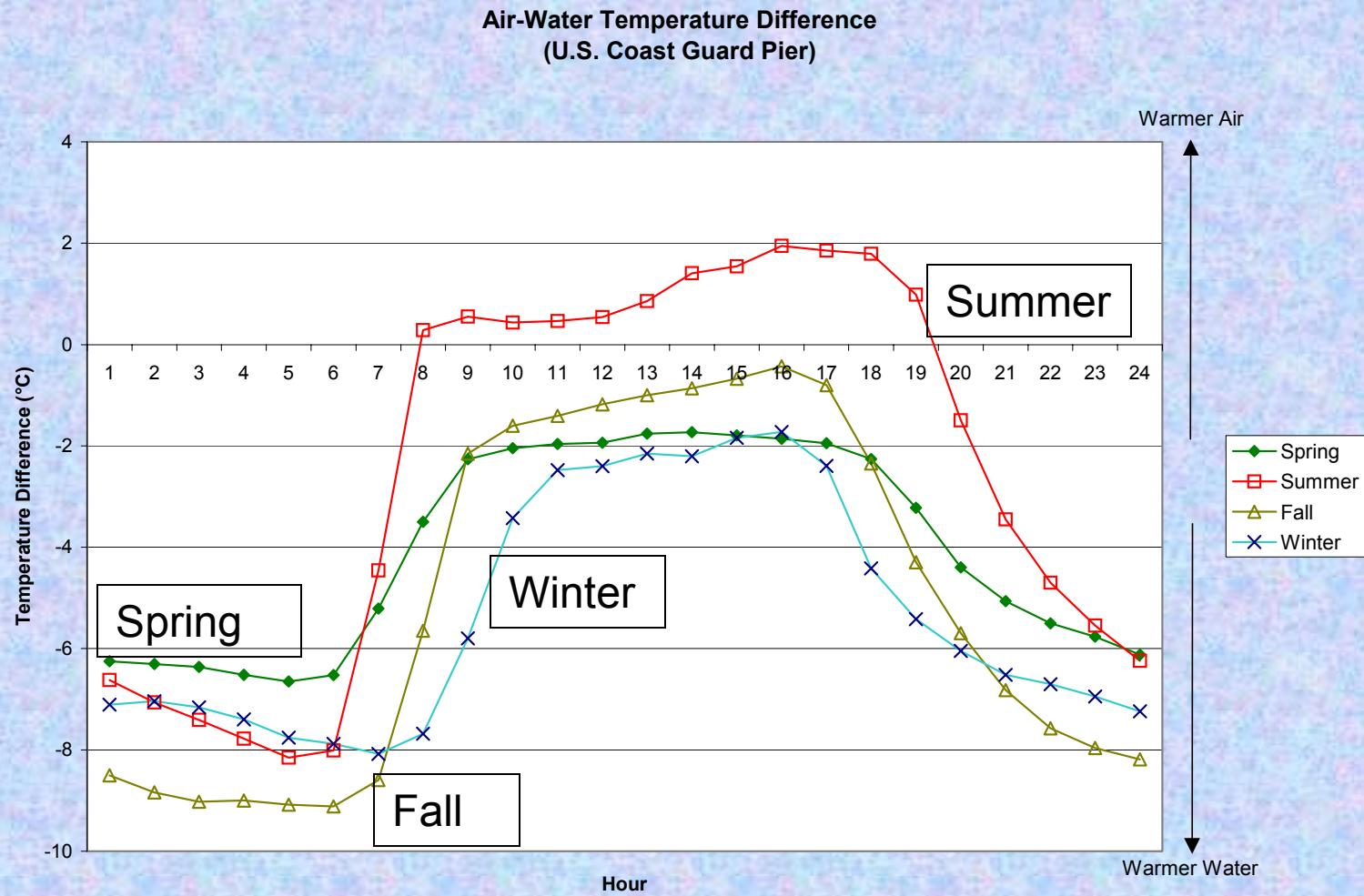
- Temporal consistency
  - Surface winds in slope-shore zone
  - Alternating onshore & offshore flow
  - Local source-receptor relationships
  - Weak winds (<3 m/s) most hours
- Spatial complexity
  - Interaction of regional & local winds
  - Drainage flow depth? Distance over Lake?
  - Convergence/divergence
  - Mixing differs greatly with location
  - Spatial detail not easily predicted

# Air & Water Temperatures Drivers for Local Winds

Air and Water Temperature  
(U.S. Coast Guard Pier)



# Air-Water Temperature Difference USCG Pier, Hourly by Season



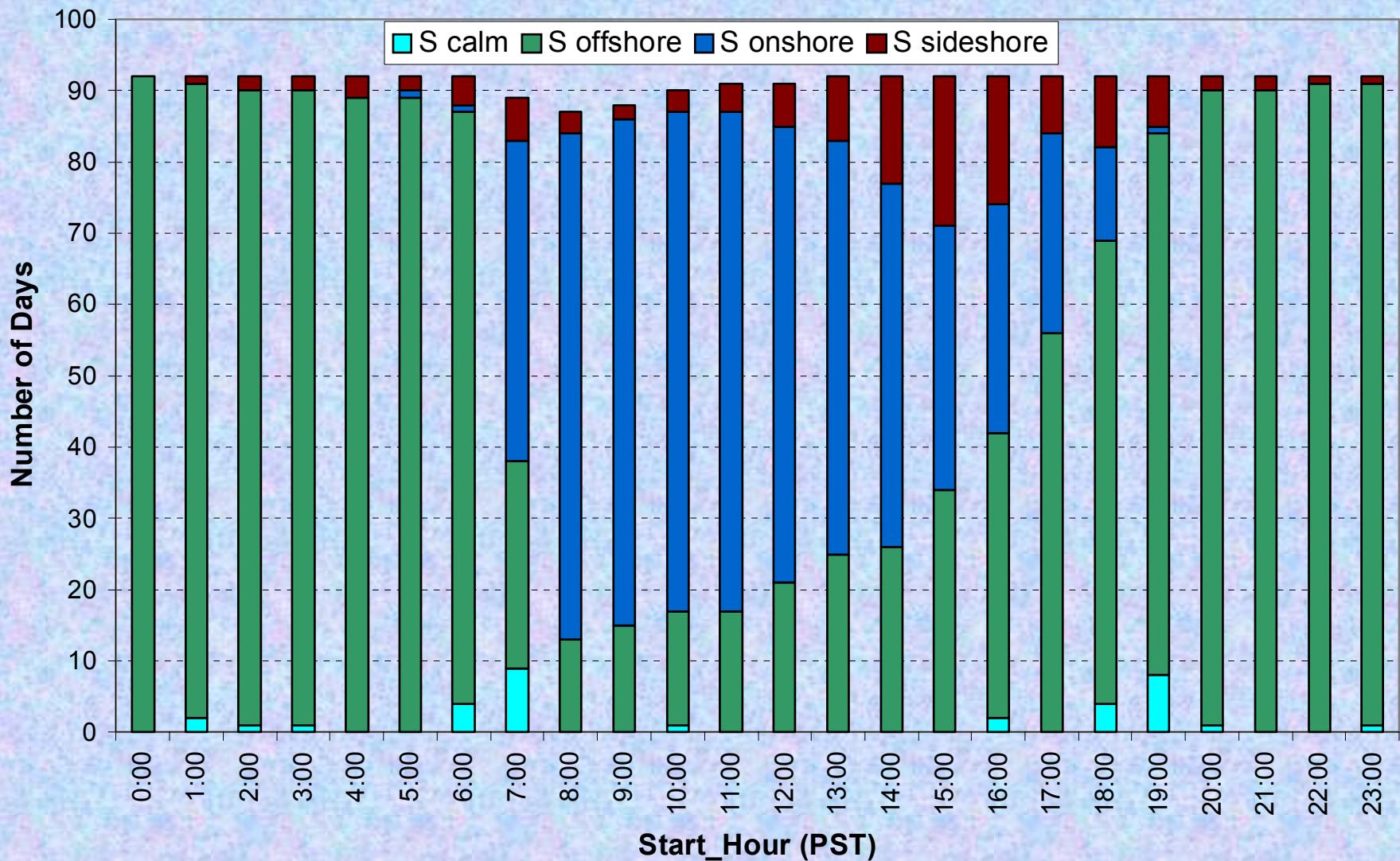
# Local Thermal Effects

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- Over land, large day-night temperature swings
- Over water, Lake moderates temperature
- Air-water temperature difference
  - Most negative in early am, summer and fall
  - Smallest difference mid-day
- Daily local winds
  - Cold shallow drainage during “night”
  - Warm onshore winds during “day”
  - Transition periods are significant
  - Alternating convergence/divergence over Lake

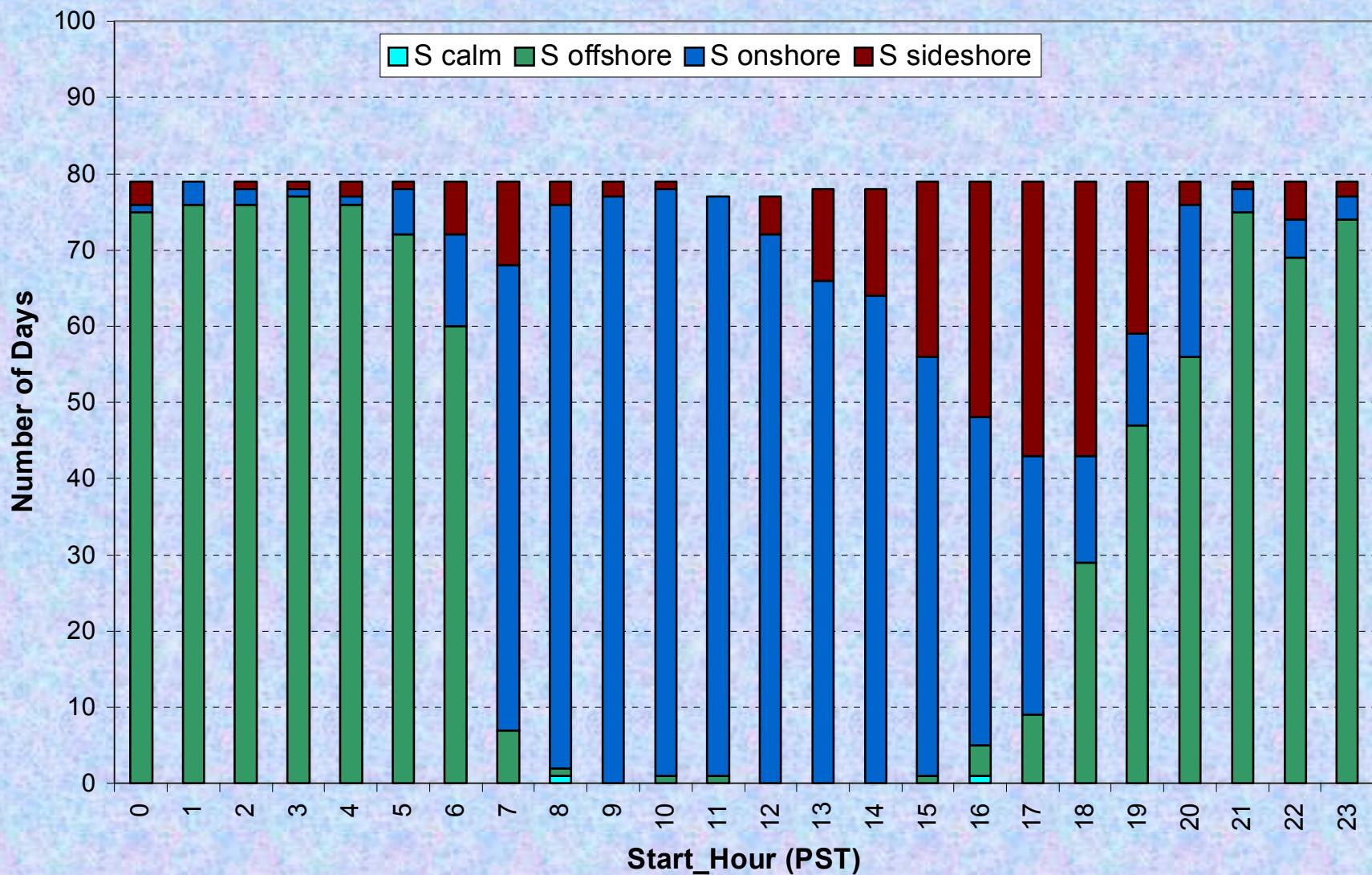
# LTADS Air Flow

## SLT – Sandy Way, Summer 2003



# LTADS Air Flow

## LF – Coast Guard, Summer 2003



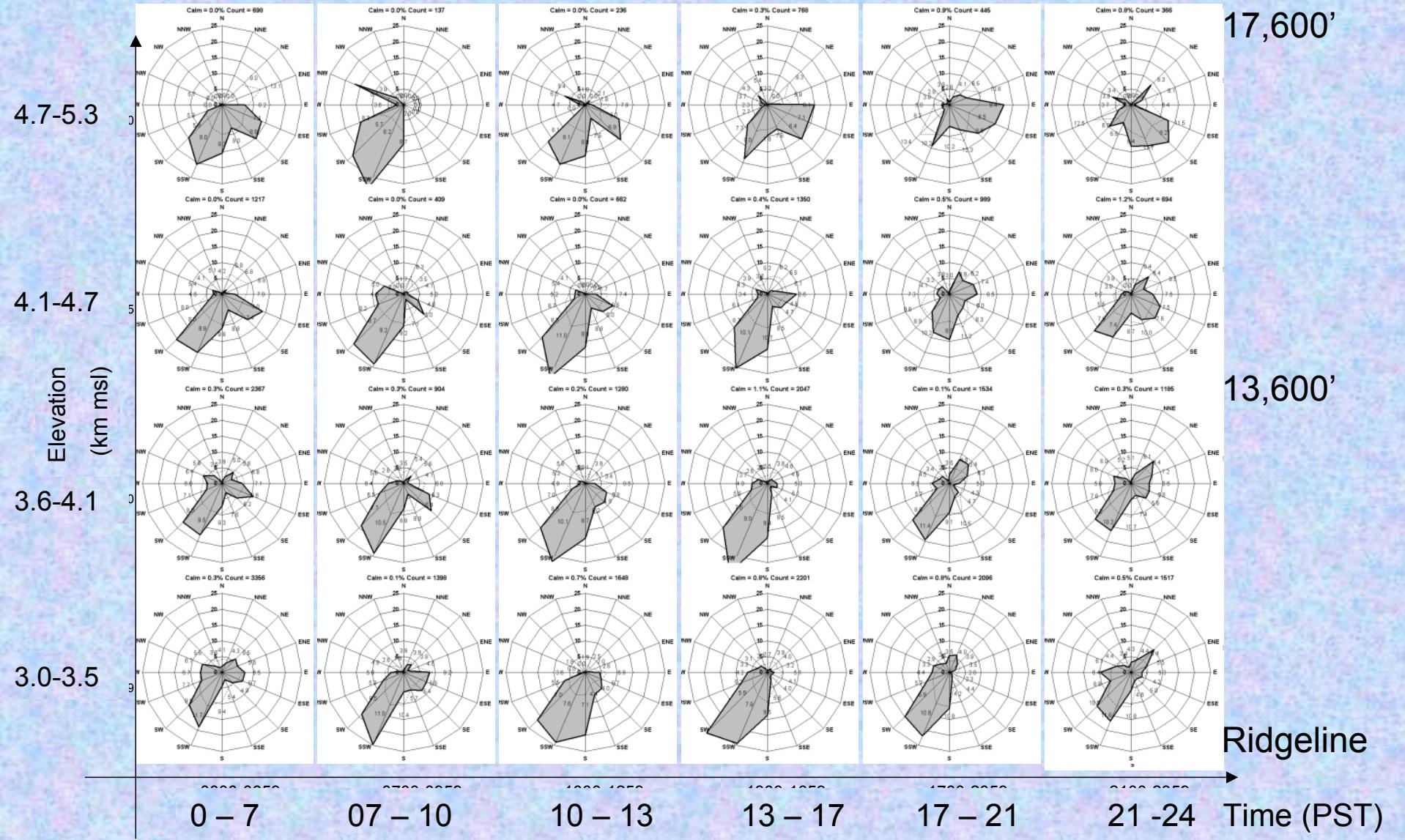
# Terrain Effects on Winds

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- Terrain blocking of regional flow, some gaps
- Aloft wind directions
  - Grass Valley ~ south
  - SL Tahoe Airport ~ southwest
  - Flow over barrier in rotating system
  - Vorticity conserved
- Channeling of thermally driven winds
- Rough forest canopy, smooth Lake
- Convergence/Divergence over Lake

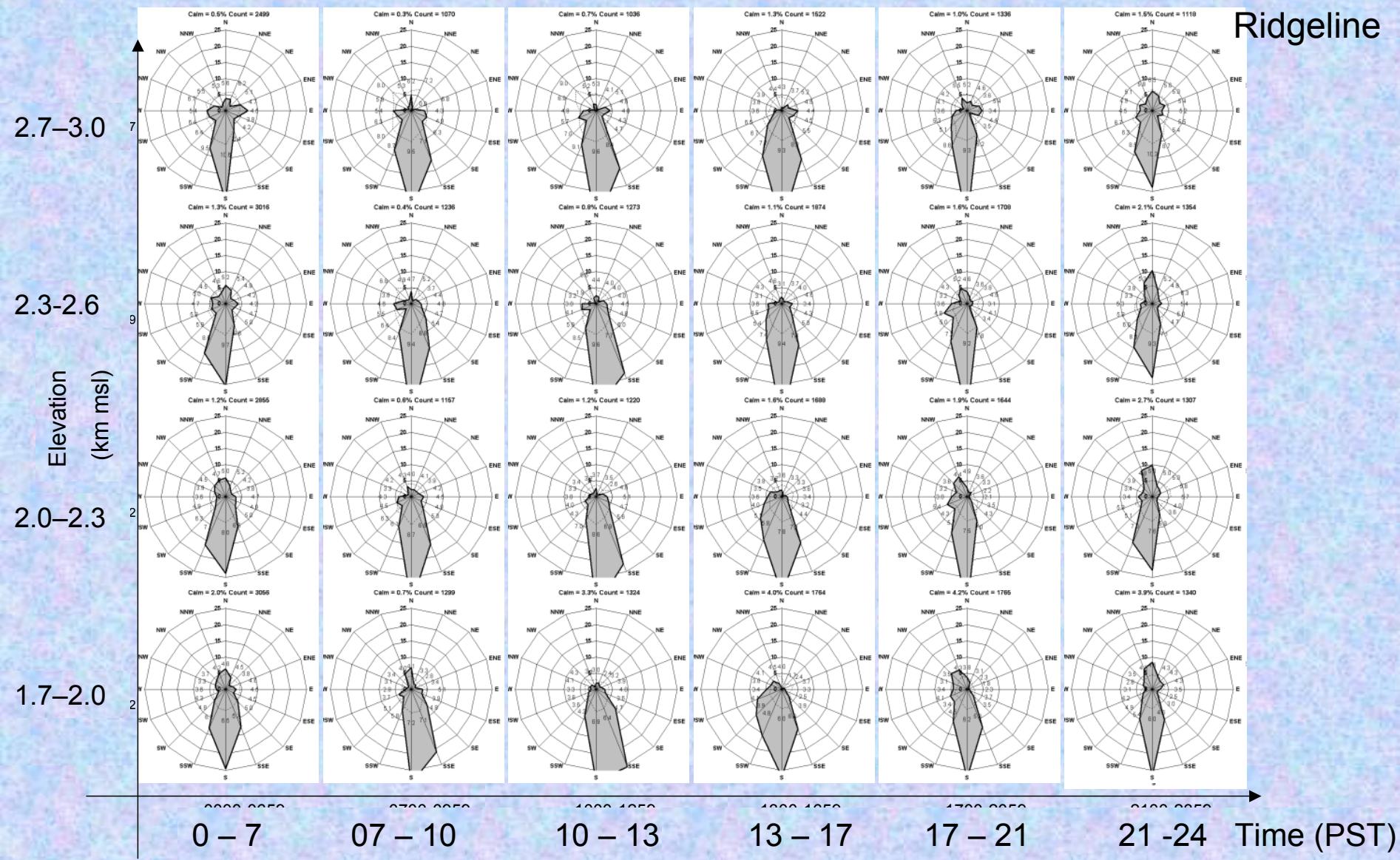
# Summer Wind Direction

## SLT Airport (3.0 – 5.3 km msl)



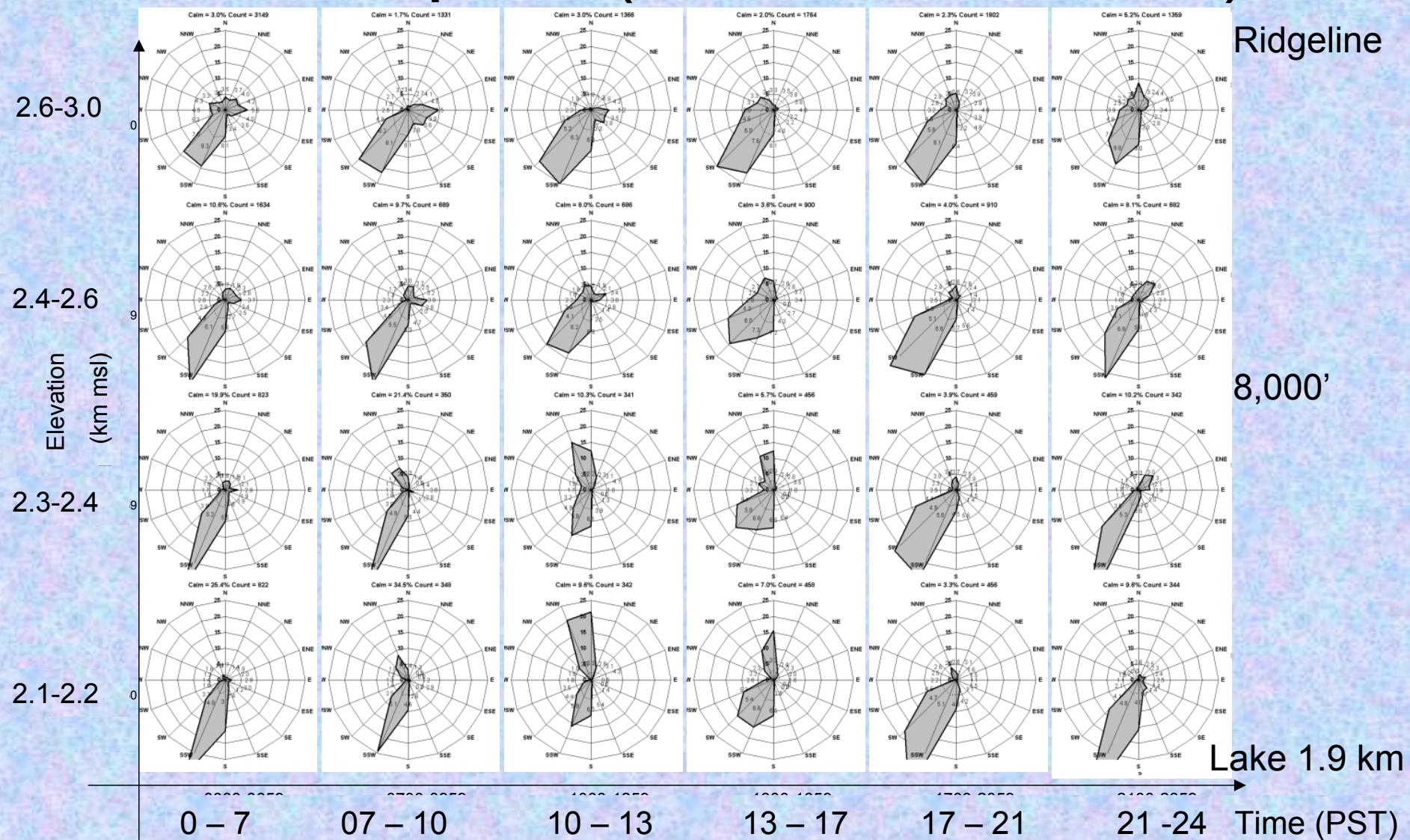
# Summer Wind Direction

## Grass Valley (1.7 - 3.0 m msl)



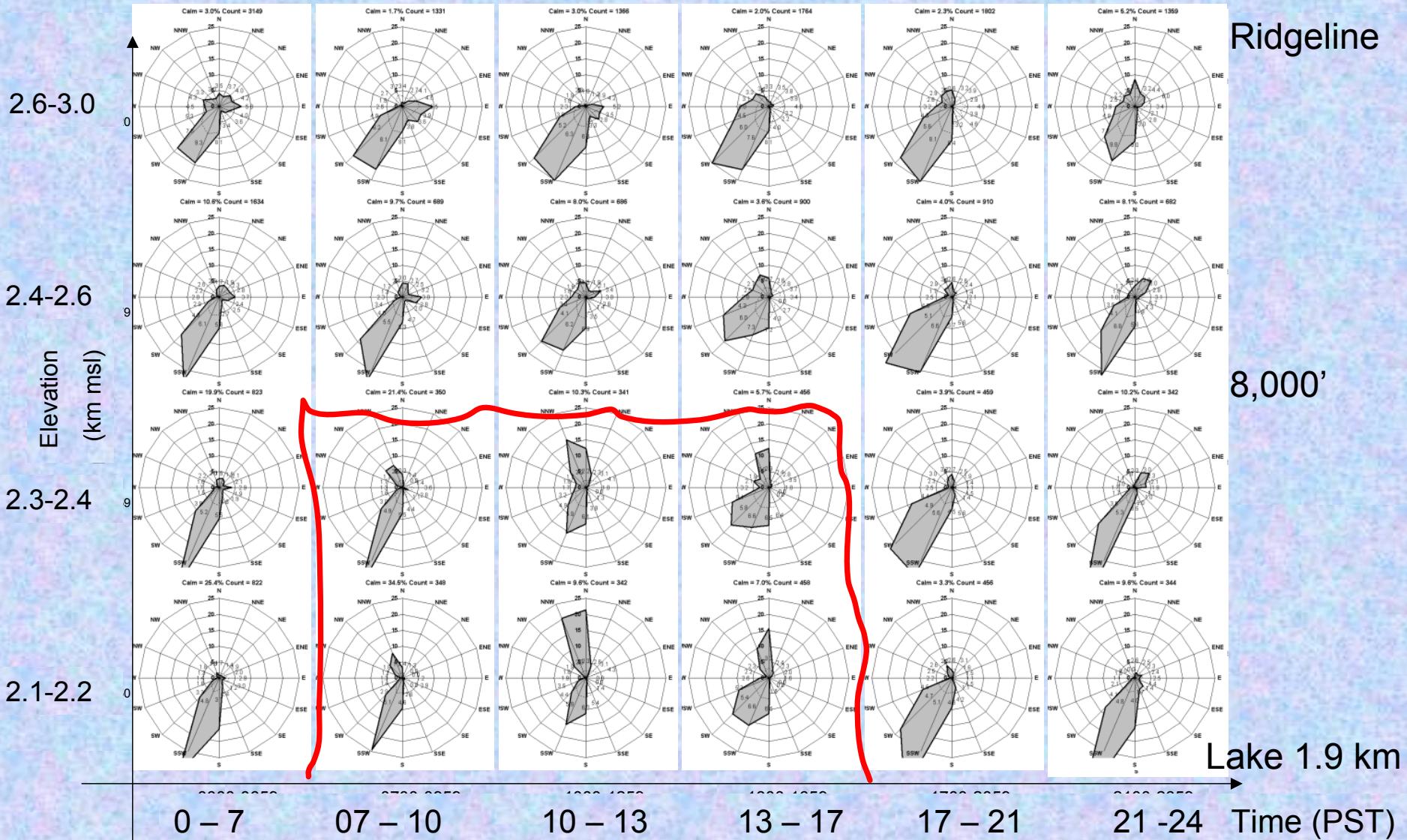
# Summer Wind Direction

## SLT Airport (2.1 – 3.0 km msl)



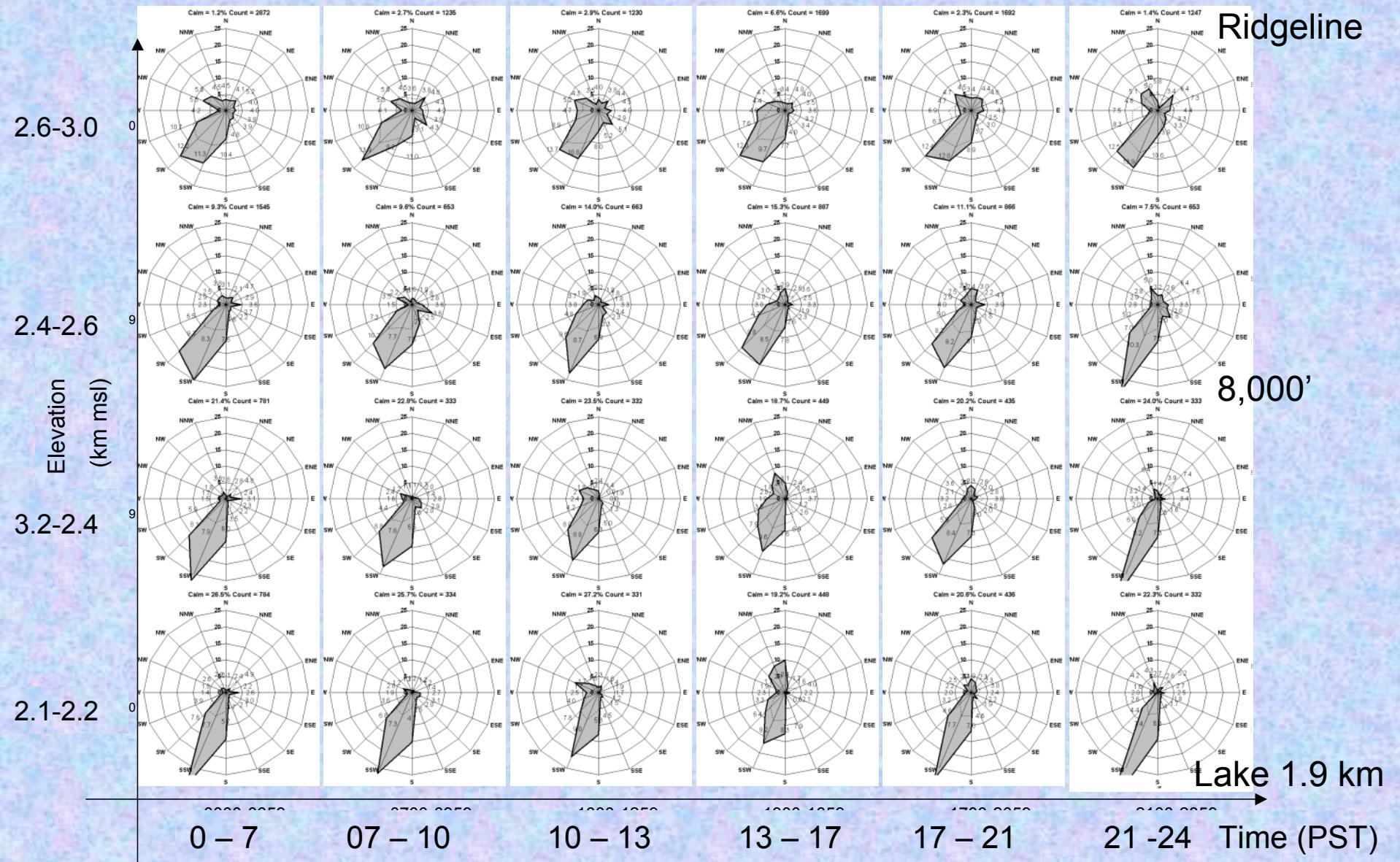
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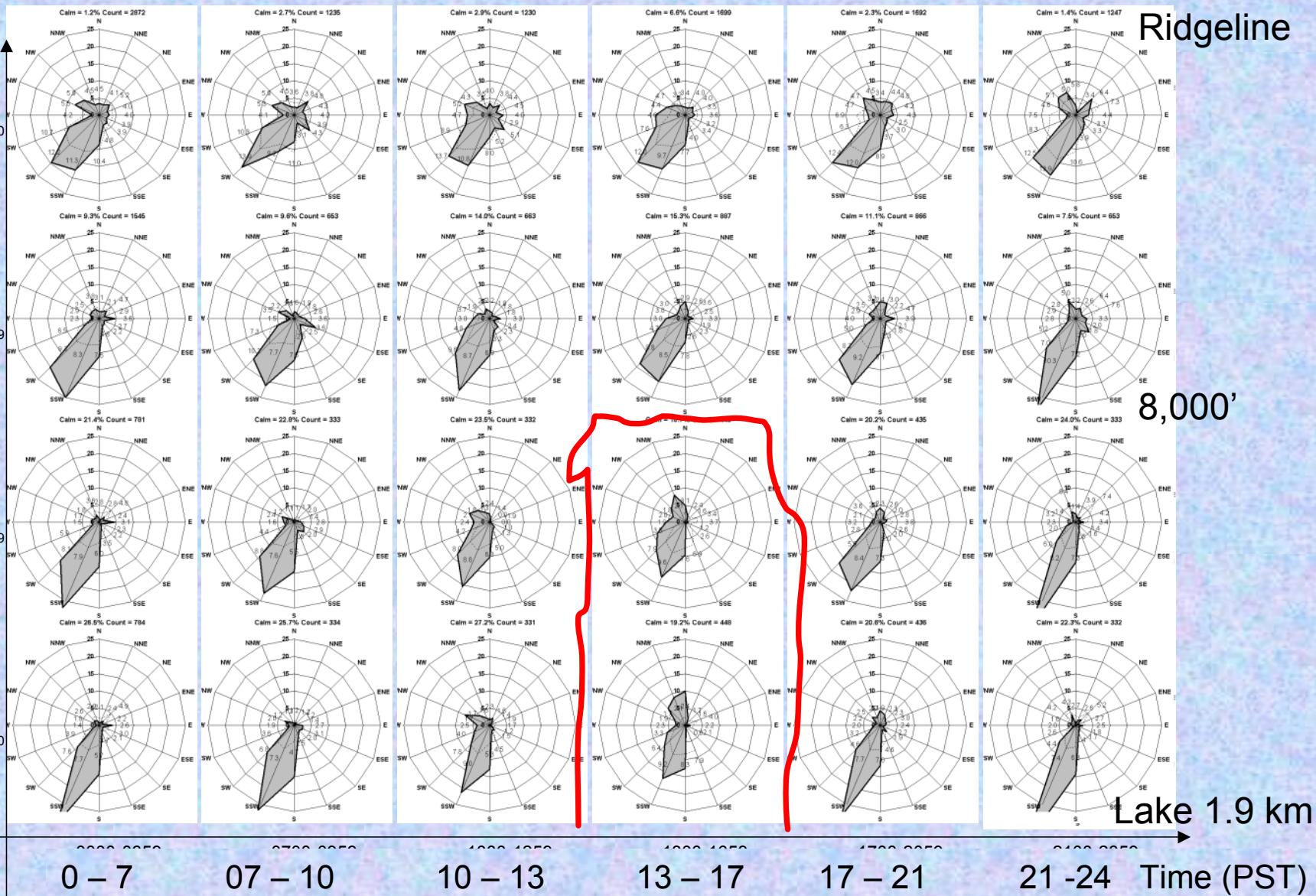
# Winter Wind Direction

## SLT Airport (2.1 – 3.0 m msl)



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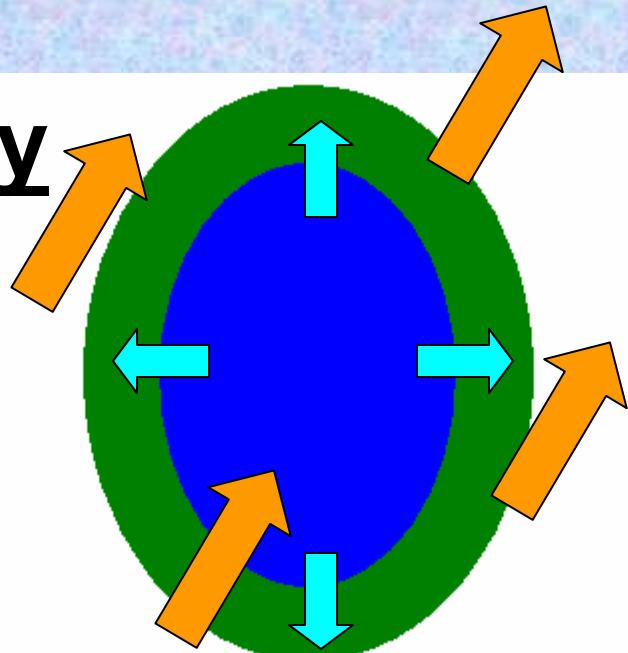


# Typical Air Flow Patterns

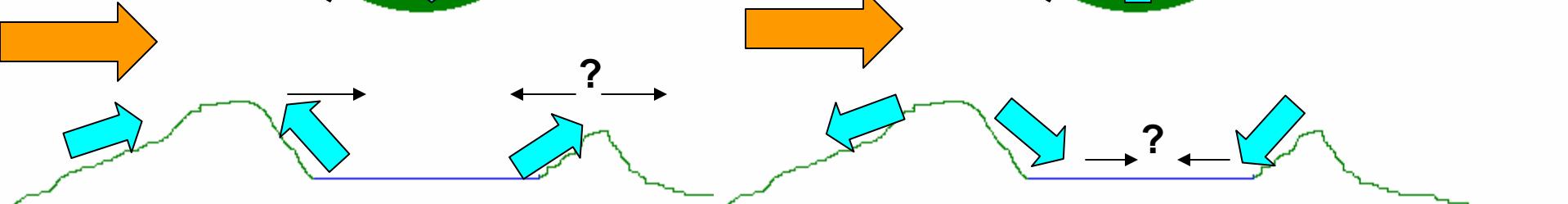
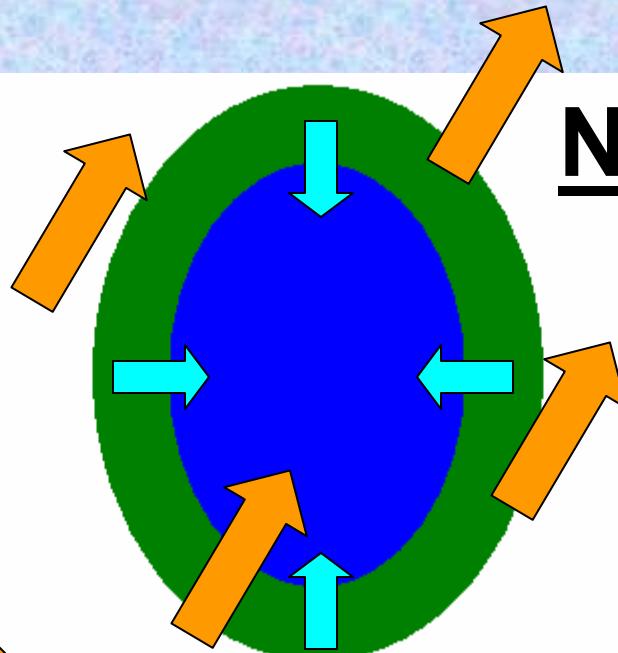
synoptic

meso-scale

Day



Night



W vertical cross section E

W vertical cross section E

# Spatially Complex Winds

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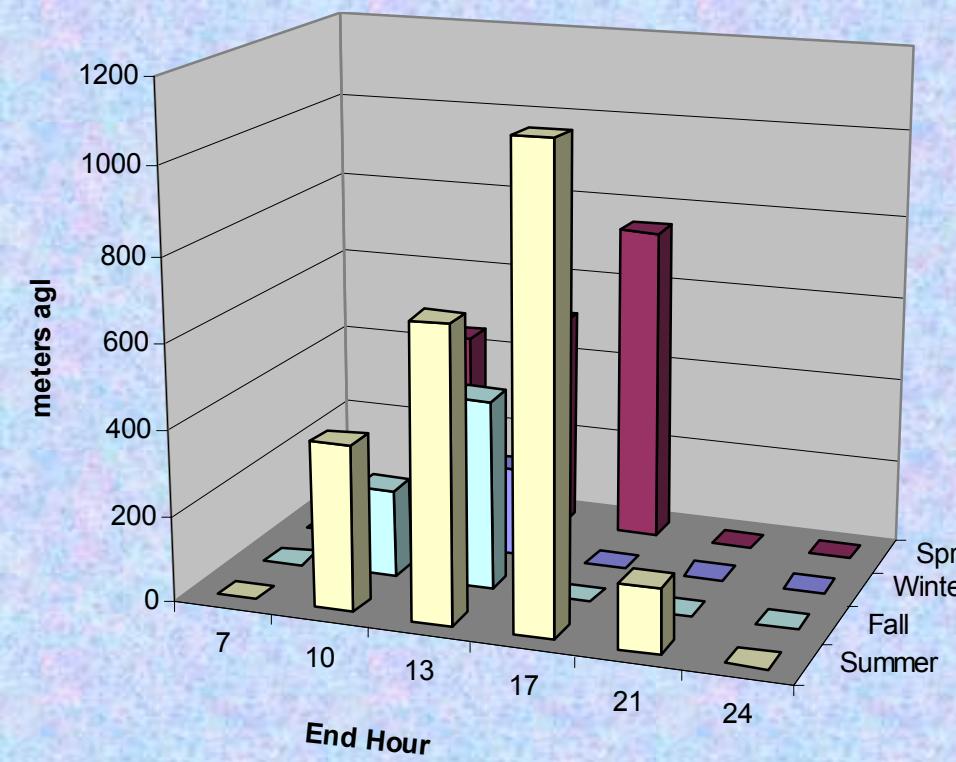
- Large Scale Terrain & Regional Flow
  - Local blocking of regional flow
  - Significant terrain gaps
  - Vorticity effects
- Local density driven flows
  - Channeling by terrain features
  - Down slope transition to flat => changes speed, mixing
  - Distance of drainage flow onto Lake?
- Organization of Lake breezes by terrain
- Slope aspect, differences in net radiation
- Multiple Processes: dynamic, spatially variable

# When does mixing “matter” to the deposition estimate?

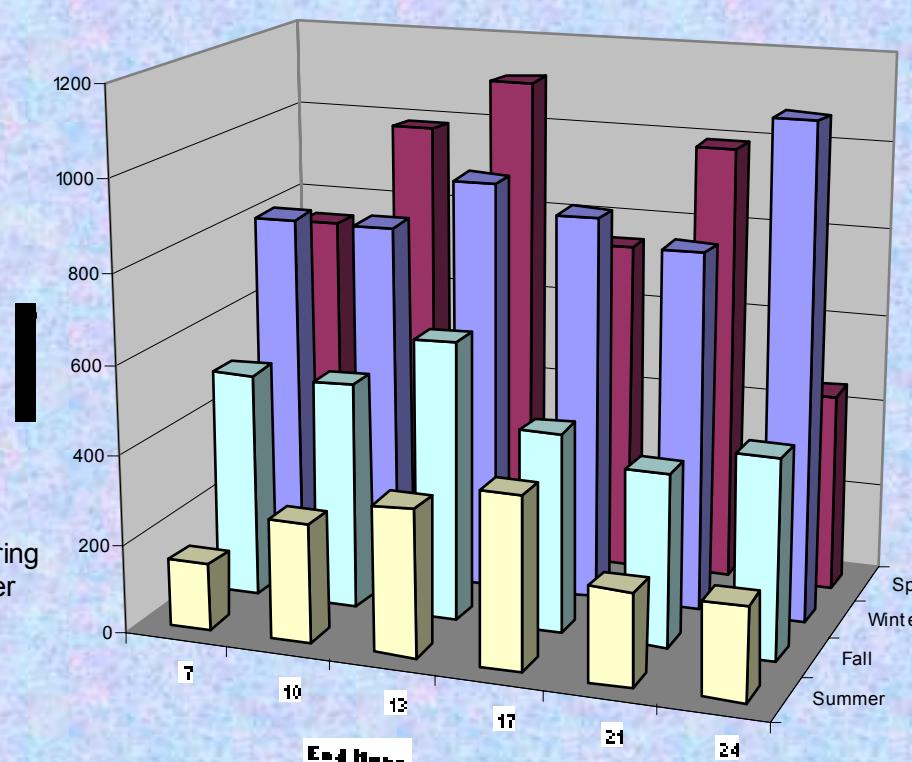
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- If concentrations differ aloft and significant vertical mixing occurs.
  - If mixed layer is shallow or very stable – surface concentration may deplete (on time scale of transport).
  - Near-source, shallow plume.
  - Mixing may modify deposition velocity.
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# Equilibrium Predictions of Median Mixing Depths (choice of surface temperatures)



Sandy Way Air Temperature



TDR1 Buoy Water Temperature

# Convergence/Divergence Effects on Mixing

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- Convergence example: Slope Drainage
  - Deepens flow
  - Vertical motion upward
  - Mixing enhanced
- Divergence example: Lake breeze
  - Subsidence
  - Adiabatic heating, inversion strengthened
  - Mixing restricted

# Spatially & Temporally Complex Mixing

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- Change in roughness & temperature at shoreline
    - Warm air over cold water – shape of stable IBL?
    - Cold air over warm water – vertical influence of buoyancy forces?
  - Advection of turbulent kinetic energy (TKE)
    - Rate of decay of TKE?
    - Rate of downward mixing of TKE?
    - TKE near Lake surface?
  - Convergence/divergence => vertical motion
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